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STUDIES FOR STUDENTS.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

V. MAMMALIA. — (*Continued.*)

HIPPOIDEA, *Equidae.* — The phylogeny of the horses has been made out by a study of the gradual changes which succeeded one another in the development of the modern form of the teeth and the foot structure. A nearly perfect series of these changes is known, and besides the direct line of the development of the horse, there have been demonstrated several side lines, all of which have become extinct. The earliest form that can be definitely stated as belonging to the line of the horses is *Hyracotherium*, from the Lower Eocene of the continent of Europe, England, and the United States. It is to be noticed that it does not occur in the lowest Eocene; thus it is not found in the Puerco of the United States, with the *Condylarthra*, but is found in the Wasatch, Green River, and the Bridger. There are four digits on the front foot and five on the hind foot, the three middle digits being functional on both feet; the fibula and the ulna of the fore part of the front and hind limbs are fully formed, and show nothing of the reduction that they subsequently undergo. The upper molars are different from the premolars, and are furnished with six tubercles, an outer pair and an inner pair, and between these another pair that is smaller.

Pachynolophus is from practically the same horizons as the *Hyracotherium* in America and on the continent. It represents a short step in advance; the ulna and the fibula are smaller and barely reach the end of the radius and the tibia. The two inner tubercles of the teeth are elongated laterally and almost join the two middle ones. This form includes, according to Osborn, a large number of genera from both the old and the new worlds that have been described from separate teeth and fragmental bones.

Epihippus from the Uinta and Bridger and *Propaleotherium* from the Middle Eocene of the Paris Basin, are very close to the *Pachynolophus*, but the inner tubercles of the upper molars are more perfectly joined to the middle tubercles, so that there is a short ridge on both the anterior and the posterior portion of the inner side of the tooth.

Mesohippus from the Oligocene of the United States, White River, and *Paleotherium* from the Upper Eocene and the Oligocene of France, are the best representatives of the next step. In these forms there are only three digits on the front and hind feet, the fourth digit on the front foot being reduced to a mere splint bone with no trace of terminal phalanges. The ulna and the fibula are greatly reduced and scarcely reach to the distal ends of the radius and the tibia. The connections between the two inner sets of tubercles of the upper molars have developed into strong cross ridges which extend well out to the outer border of the tooth and nearly touch the anterior edges of the corresponding tubercles.

Anchitherium is now regarded as little off the main line of descent of the true horses, but as it represents very closely the succeeding stage that is properly indicated by a poorly known form, *Desmatippus*, from the Deep River beds of Oregon, it may properly be described here.

Anchitherium is one of the most common forms of the Upper and the Middle Miocene of the continent of Europe and the United States. The fourth digit of the front foot is reduced to a mere ossicle of bone at the upper end of the third digit. The distal ends of the ulna and the fibula have entirely disappeared, so that the bone ends free in the middle part. The teeth show the cross ridges of the upper molars extending out to the outer tubercles and joined with them. One of the most important changes of the series that developed the horse appears in this form; the enamel on the upper portion of the cross ridges disappears and permits the cement below to appear at the surface. Now, as the cement is softer than the enamel, the wear of the tooth will serve to keep this inner part lower than the enamel walls, and there will always be sharp edges to serve for grinding up the grass and other herbage that forms the food of the animal.

Protohippus and *Merychippus* from the Pliocene of North America are the next forms in the series. The two lateral digits of the feet, two and four, are shortened and do not reach the ground, though they still retain all the phalanges. The ulna and the fibula are reduced to short splints, confined to the proximal ends of the radius and the tibia. The molars are very horse-like in the fact that all the tubercles have lost the enamel from the upper surfaces, and there are great "lakes" of cement, bordered by sharp enamel edges, for grinding the food.

Hipparion is a form somewhat off the line of the horses, but differs little from the *Protohippus*. It was very common in the Miocene time both in North America and in Europe. It extended up into the Pliocene in Africa and Asia.

Pliohippus and *Equus* are from the Pliocene deposits of most of the world, and from there upward the deposits of the Pleistocene and the recent times show their presence, except that *Pliohippus* is absent in the Recent. It is of interest to note that though the continent of North America was undoubtedly the original home of the horses and the theater of their greatest development, that at the end of the Pleistocene time they seem to have disappeared from the continent, and were only reintroduced by man when the Spaniards brought them over to aid in the conquest of Mexico.

The last two genera are distinguished by the reduction of the two lateral digits to two splint bones on the proximal end of the cannon bone and the nearly complete loss of the ulna and the fibula; the latter remains only as the olecranon process.

The phylogeny of the horse series has thus been arranged by Mr. Farr, a late writer on the subject.

Pliocene to Recent *Equus*
Hippidium

Loup Fork	*Protohippus*
	Hipparion
Deep River	*Desmatippus*
	Anchitherium
John Day	*Mesohippus*
White River	*Mesohippus*
Uinta	*Epihippus*
Bridger	*Pachynolophus*
Wasatch	*Hyracotherium*
	Paleotherium
Puerco	*Condylarthra*

The earliest of the horses must have presented a very different appearance from the horse as we know it. They were scarcely larger than a small dog and had rather the appearance of one than of a horse. The Miocene members of the group were about the size of a small pony, with very delicate limbs. According to Osborn, they were, in all probability, marked very much like the zebra. The *Anchitherium*, *Hipparion*, and the earliest true horses were somewhat smaller than the recent horse, but could not have been very different in their external appearance.

Paleotheridae.—This is the more primitive of the two families. It is known only from the Upper Eocene deposits of Europe, but there are several closely related later forms both in Europe and America. *Anchitherium* and *Pachynolophus*, described among the *Equidae*, are by some authors regarded as more closely related to the *Paleotheridae.*

Paleotherium, from the Upper Eocene of the Paris Basin, is the typical genus. The dentition is complete, but the premolars have assumed the appearance of molars. There were three toes on each foot, all reaching to the ground. The surfaces of the teeth are covered with enamel and have not begun to show the "lakes" of cement that characterize the teeth of the true horses. The largest, from *P. magnum*, was about the size of a rhinoceros.

The TAPIROIDEA has the two families *Tapiridae* and *Lophiodontidae.* In common with the other Perissodactyls, they seem to have their origin in the earliest Eocene from some animal closely related to the *Hyracotherium*. In general they were stout-bodied animals of medium size, with three digits on the posterior foot and four on the anterior; the upper teeth developed in the more recent forms a pair of transverse parallel ridges that are characteristic of the group.

Early in the history of the group it divided into the two families, which took different lines of development, the *Tapiridae* working out the condition of the modern Tapirs and the *Lophiodontidae*, which assumed somewhat the characters of the rhinoceroses and became extinct in the late Eocene or Middle Miocene.

Tapiridae. — The line of development of the modern Tapirs is expressed as follows by Wortman and Earle: *Systemodon* of the Wind River; *Isectolophus latidens*, Bridger; *I. annectens*, Uinta; *Protapirus*, White River, and possibly *Tapiravus*, of the Loup Fork. Speaking of this family, Smith Woodward says: "The family thus characterized dates back to the Lower Miocene (White River Formation) in the United States of America, and apparently to the same remote period in Europe. In the Tapirs of this early date the premolars are slightly simpler than those of the surviving genus *Tapirus;* while *Tapiravus*, ranging through the Miocene and Pliocene of North America, is still somewhat primitive in the same feature. The typical *Tapirus* itself, however, is represented in Europe by several fine specimens from the Lower Pliocene of Eppelsheim, Hesse-Darmstadt (*T. priscus*), and from the corresponding formations in Hungary and southeastern Austria; also by remains from the Pliocene of France and Italy, and by detached teeth from the Red Crag of Suffolk. It is also to be noted that other teeth, indistinguishable from those of *Tapirus*, occur in an Upper Tertiary (probably Pliocene) formation in China. It is thus evident that during Miocene and Pliocene times these animals ranged over most of the warm and temperate lands of the northern hemisphere. Hence is explained the remarkable distribution of the existing Tapirs, which are confined to two widely separated areas, namely,

(1) certain portions of the Indo-Malayan region, and (2) the tropical parts of America."

Lophiodontidae.—In defining this family Osborn and Wortman indicate its position by referring to it as "A family of Lophodont Perissodactyls intermediate in position between the *Tapiridae* and the *Hyracodontidae.* The genera referred to this family are *Lophiodon* from the Middle Eocene of Europe, *Heptodon* of the Wasatch, *Helaletes* of the Bridger and Uinta, and *Colodon* of the White River.

Lophiodon has been considered as a very widely spread form in the Middle Miocene of Europe, but it now seems to be the opinion that many species have been wrongly referred to it that should properly be placed with genera *Colodon* and *Helaletes.*

The CHALICOTHEROIDEA is sometimes regarded as a separate suborder, the *Ancyclopoda* not being related directly to the Perissodactyls. They were aberrant animals related on the one hand to the Perissodactyls and on the other to the Edentates. In the structure of the foot there is a striking resemblance to the structure in the great ground sloths, *Gravigrada*, of the late Tertiaries of America. It was five-toed and turned so that the weight of the animal rested upon the outer side of the foot, and the digits terminated in strong claws. The teeth, on the other hand, were strikingly like the teeth of the Perissodactyl series. The suborder, or super-family, had its greatest development in the Miocene and Pliocene times.

Homalodontotherium is from the early Tertiary deposits of Patagonia. The primitive character is indicated by the complete dentition of the animal and the absence of any diastema. The humerus was very short and stout, indicating possible fossorial habits.

Macrotherium is a smaller form from the Middle Miocene of France and Germany. The condition of the teeth indicates a somewhat more advanced type. The fore limbs were much longer than the hind. The best known species was about nine feet in length.

Chalicotherium is the best known form from the United States.

It is found most commonly in the Loup Fork. Many teeth resembling *Chalicotherium* have been named from all parts of the world, notably China, Hungary, and Germany, indicating a very wide range for the genus.

From the Tertiary deposits of South America, in Patagonia, and the Argentine Republic come the remains of many animals that seem to be without representatives in any other part of the world. In some respects they resemble the Perissodactyls and, indeed, one of the orders is regarded by Zittel as a possible family of that group. Their relationships are, however, still too imperfectly known to permit of much discussion. Three orders are known, the *Typhotheria*, *Toxodontia* and *Litopterna* (*Proterotheridae* Zittel). Smith Woodward says they "must be little modified descendants of very primitive eutherian mammals."

TYPOTHERIA.—The order is peculiar among the ungulates, in that it possesses a well-developed clavicle. The limbs are unmodified and the dentition is nearly complete.

Pachyrucus and *Typotherium* are the best known genera: The first was somewhat the smaller of the two. The teeth are somewhat rodent-like in appearance and the dentition is not complete. There was a considerable diastema between the enlarged incisors and the premolars, the canines were wanting.

TOXODONTIA.—The second order of the South American group resembled in many of its characters the first, but lacked the clavicle, and the limbs were modified toward the ungulate type, there being but three toes on the fore and hind feet The animals were much larger than the previous order, reaching nearly the size of the rhinoceros in the genus *Toxodon.* The bodies of the animals were short and stout, and the head was placed on a very short neck low on the body. The two typical genera *Toxodont* and *Nesodon* are both from the Tertiary of South America, but *Nesodon* is from the earliest strata.

LITOPTERNA.—This order was much farther developed than the preceding, and in general appearance could not have been far from that of the modern horse. The primitive condition is indicated by the complete dentition and the stage of development of the limbs. There were forms with only a single digit remaining, and others with three, resembling the Perissodactyls in this character, but the same animals had the tarsus built on the Artiodactyl plan so that they can belong to neither group.

Thoatherium and *Proterotherium* are small animals from the Santa Cruz formation of Patagonia. They were monodactyl, the second and fourth digits being either completely lost or greatly reduced in size.

Macrauchenia was much larger than the other two, and resembled the modern camel in size and some of the skeletal characters. The limbs were functionally tridactyl. The genus comes from the Pleistocene deposits of Argentina.

AMBLYPODA.—This suborder reached its greatest development in the Eocene time and died out at the close of the same period. The members of the suborder were all rather stout animals that reached, near the time of their extinction, the size of an elephant, or nearly so. The brain was very small and almost devoid of convolutions; there were five toes on each of the feet, and the bones of the limbs were complete, *i. e.*, the tibia and the fibula, and the radius and ulna, were separate and perfect. The group is generally divided into two families according to the characters of the teeth, skull and limbs.

Coryphodontidae were animals limited to the lowest Eocene of America, England and France. The greatest number and the most perfect specimens have been obtained from the Wasatch formation of the western part of the United States.

Coryphodon, the typical genus, was a short and rather stout animal about six feet long; the skull was elongated in the facial region with a rather broad muzzle armed with strong incisor and canine teeth; the feet were very short and strong with blunt toes. The brain cavity was very small and limited to a small part of the skull. The surface of the skull was without any bony excrescences or with only very faint ones.

Dinocerotidae: found in the Middle Eocene, Bridger; animals larger than the preceding family, and in general stouter and stronger. The skull was longer and without the anterior enlargement of the muzzle; the dentition was weaker in that the incisors were lost entirely or in part, and the molars and premolars were small and weak. The canines were greatly enlarged and extended from the jaws as tusks that were protected by a flange of the lower jaw. The top of the skull shows three pairs of bony protuberances that were possibly the bases of horns. The brain was little, if in advance, of that of the *Coryphotondidae*.

Dinoceros (*Unitatherium*).—Characters given in the description of the family.

ARTIODACTYLA.—The families that we shall consider are the *Anthracotheridae*, the *Suidae*, the *Oreodontidae*, the *Hippopotamidae*, the *Camelidae*, the *Anoplotheridae*, the *Tragulidae*, the *Protoceratidae*, the *Cervicorna*, and the *Cavicorna*.

Anthracotheridae.—This is an extinct family that is found chiefly in the deposits of Europe and the East Indies. The earliest member of the group occurs in the Eocene of Europe. During the Miocene time it spread over the whole continent of Europe and over North America. The whole group appears to have died out in the Miocene. The animals were large, about the size of the rhinoceros, and from that down to the size of a pig. The head was long and low, with little development in the cranial region and a consequently small development of the brain. The teeth are of the low multitubercular type that is characteristic of the pig family. The feet have four toes on each foot and the metapodials of the middle pair are not united.

Anthracotherium, Oligocene, of Europe, England, and India, and North America.

Ancodus, Oligocene, of Europe, and North America.

Merycopotamus, Pliocene, of India.

Suidae.—This is a very large group that contains the existing hog. There are many primitive characters in the group, such as the complete dentition, and the generalized multituberculate teeth. The limbs have either four or two toes and the metapodials of the middle pair are not united. The living members of the family are found in Asia, Africa, Europe, and America.

Fossil forms of the group are found in the Eocene of Europe and North America, but the greatest development of the family came from the Pliocene to Recent. The origin of the *Suidae* is not at all well known, but there seems to be little doubt that they are the specialized branch of some carnivorous stem.

Achænodon, from the Bridger Eocene, has very strong canines and the cheek teeth are similar in many respects to those of the primitive *Carnivora.*

Elotherium, from the Oligocene of Europe and the United States, White River, is one of the ancestral forms. The head is long, the posterior teeth are multitubercular, the premolars are conical, and the canines and incisors are long and well fitted for grasping. The limbs were peculiarly long, and altogether the animal seems to have been a rather vicious type of carnivorous hog that had the running powers of a deer.

Platygonus, from the Pliocene and the Pleistocene of the United States, was a very small form that seems to have been the direct ancestor of the peccary.

Sus, the true hog, appeared in Europe and Asia, in the Upper Miocene and has continued ever since. There is no native member of the genus in the Americas.

Hippopotamidae.—The Hippopotamus is not known earlier than the Pliocene, and occurs in deposits of that age in England and in India. The existing forms are confined in Africa.

Oreodontidae.—This is an extinct group that is confined to the Miocene and the lower Pliocene of the United States. It is primitive in all of its characters; the dentition is complete and the fore limb has five digits; the metapodials are not united. One peculiar thing is that the anterior lower premolar tooth passed forward and acted as the canine, while the canine assumed the aspect and the function of an incisor. The sense of hearing was very acute, the bulla of the ear reaches, in some of the later forms a very large size. The animals were all small, never reaching a size larger than that of a Newfoundland dog, and in most cases were much smaller. From the manner of the occurrence of their remains it seems that they lived near the banks of the lakes or streams and gathered together in great herds. The time of their greatest development was the Oligocene, and in the beds of the White River deposits the remains are found in the greatest abundance.

Protoreodon.—Uinta.

Agriochoerus.—White River, a peculiar form that had the toes terminated in sharp claws like the Sloths.

Oreodon.—White River.

Leptauchenia and *Cyclopedius.*—Upper Miocene, Deep River.

Camelidae.—The camels seem to have developed first on the North American continent in the Middle Eocene, Uinta, and Bridger, and to have died out in the Pliocene. They are peculiar in the much elongated head and the deficient anterior dentition. In the older forms the metapodials are separate as in the families already described, but in the later ones the two are joined and only a thin layer of bone separates the two medullary cavities.

In South America during the Pliocene time there were developed a large number of forms that became extinct, with the exception of the existing Llama. The genus *Camelus* appeared in Asia in the Lower Pliocene without known forerunners, and in North Africa at the beginning of the Pliocene.

Leptotragulus.—Unita.

Poebrotherium.—White River.

Protolabis.—Loup Fork.

Procamelus.—Loup Fork.

Anoplotheridae.—Small extinct forms that were developed in the Eocene of Europe and died out in the lower Miocene. They seem never to have extended beyond the limits of the continent of Europe. They were among the first to develop the selenodont form of teeth that is the characteristic form of the deers and the most of the ruminants.

Anoplotherium.—Eocene.

Dichobune.—Eocene.

Xiphodon.—Eocene.

Cœnotherium.—Miocene.

Tragulidae.—Small forms that began in the Eocene of Europe and spread over nearly all parts of the world in the Miocene and the Pliocene. *Tragulus* of the East Indies and *Hyæmoschus* of the west African region are still living members of the group.

The group is highly specialized. The median metapodials alone are functional, the second and fifth are reduced to mere splints at the upper and lower ends of the middle pair. The carpals and tarsals are united in some forms and the metapodials are elongated and united in many of the forms to a cannon bone. The elongation of the limb, due to the length of the metapodials indicates the great running and leaping powers of the form. The upper incisor teeth are wanting and in the males the upper canine is elongate and appears outside of the mouth as a long tusk.

Lophiomeryx.— Europe, Upper Eocene.

Prodremotherium.— Europe, Upper Eocene. Remarkable for the slender skeleton and the length of the limbs.

Gelocus.— Europe, Oligocene.

Dremotherium and *Amphitragulus*.— Lower Miocene, Europe.

Dorcatherium.— Miocene, Europe and Asia.

Leptomeryx and *Hypertragulus*.— North America, Miocene.

Tragulus appeared in the Pliocene of Asia, and *Hyaemoschus* is unknown from fossil remains.

Protoceratidae.—A small family resembling in many respects the *Tragulidae* of the old world. The group is confined to the upper part of the White River formation of the United States. There is only one well-known genus, the *Protoceras*, an animal that resembled the modern antelope, probably, as much as any recent form. The male is peculiar in the fact that the skull bore two or three pairs of horn cores. The female was without horns.

Cervicorna.—This essentially modern group appears in the Miocene of Europe and North America and has a considerable number of the members still living. The males have, in nearly every case bony horns that are shed every year, differing in this respect from the succeeding group in which there is a permanent horn core, and the horn proper is not shed. The upper incisors are deficient or entirely absent, and the upper canines are either absent, small, or enlarged as in the *Tragulidæ*. The carpals and the tarsals are anchylosed in some forms and the metapodials are united to form a cannon bone. The whole structure of the skeleton indicates the lightness and the speed of the deer tribe.

Blastomeryx.—North America, Miocene and Pliocene.

Paleomeryx.—Europe, Miocene.

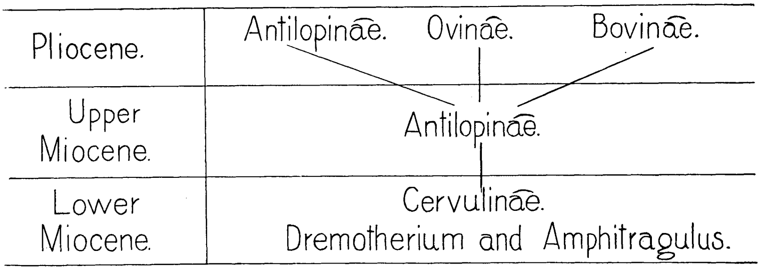
Helladotherium.—Europe and Asia, Upper Miocene. This form with the *Samotherium* of Europe are interesting as being the ancestors of the giraffe, *Camelopardalis*, which is found in the same deposits and then disappears from the record to appear again in the Recent in Africa.

Sivatherium and *Bramatherium* are large forms, strikingly resembling the moose, which are known from the Miocene deposits of India and unknown since.

Most of the modern forms of the family seem to have appeared in the Pliocene and their remains are especially well preserved in the European deposits, but not until the Pleistocene time do the deposits indicate anything like the profusion of numbers and the widespread distribution of the group that obtains at present.

Cavicornia.—The group is in few particulars different from the *Cervicornia.* The horns are not deciduous or bony, they are present in both sexes. The teeth are similar in many respects, but the upper canine is always lacking as well as the upper incisors. The metapodials are always united to form a cannon bone and the lateral digits are the merest rudiments or are completely absent. In general the skeleton is very similar to that of the preceding group, but in many of the forms it is much more robust. One thing characteristic of the group is the width of the brow. Where the horns are set close together in the *Cervicornia*, in this group they are wide apart, a condition that reaches its greatest development in the *Bovidae*, the cows and buffaloes. It is of interest to note that the same loss of the enamel which took place on the upper surface of the teeth of the *Equidae* also took place in the *Artiodactyla*, and the later forms have the enamel entirely removed from the tops of the tubercles and the spaces between the walls filled up with a softer and more rapidly wearing cement.

Three general divisions may be recognized, the antelopes, the sheep and the bovine tribe. The oldest of these, the antelopes, appeared in the Miocene of Europe and southern India. They seem to be derived directly from the *Cervulinae*, a subfamily of the *Cervicornia* represented by *Dremotherium* and *Amphitragulus*. During the Pliocene the three groups were differentiated.



PROBOSCIDEA.—The origin of this suborder is not at all well understood, the first members of the group are found in the Miocene time and in all the essential characters are as well developed as the most advanced of the living forms. In many of their characters the *Proboscidea* are very primitive; the structure of the feet and of the carpus and tarsus, the structure of the limbs and other parts of the body, are such as are found in the earliest ungulates. The development of the proboscis and the correlated shortening of the neck and the development of the peculiar dentition are the only characters that define the group. The most characteristic feature is the development of the incisor teeth as tusks which in some forms occur in both the upper and the lower jaws, in others in the lower jaws, and in the most modern forms in the upper jaws. In the earliest forms there were many teeth in the jaws, each one with strong transverse ridges completely covered with enamel; in the advance of the group the ridges on the teeth seemed to multiply until they became very numerous, and at the same time the enamel disappeared from the top of the ridges, leaving the softer dentine exposed, which wore away more rapidly than the enamel and left strong, grinding ridges such as are found in the horse. With the advance in the structure of the teeth appeared the degeneration of the dentition as a whole, so that the modern elephant has never more than one cheek tooth at a time in the jaw; the teeth appear successionally, the anterior one first and so backwards during the life of the animal.

Dinotherium is the earliest known member of the group. It was characterized by the development of a pair of down-curving tusks in the lower jaw and a complete absence of incisors in the upper jaw. There was a more or less complete dentition, the jaw containing two premolars and three molars. The single complete skull known is about three feet long. The genus is known from the Miocene of Bohemia and from the Pliocene of Central Europe and India. It is unknown from America.

Mastodon differed from the preceding in the presence of fewer molar teeth and in the presence of tusks in both the upper and lower jaws or in the upper jaw alone. The molar teeth exhibit many variations in form, but in general the surface has a tendency to be distinctly tuberculated, the transverse ridges multiplying and dividing into outer and inner halves. In size the animal was nearly as great as the elephant. It was very common in the later Tertiary and forms have been discovered in formations as early as the Middle Miocene in Central Europe. In the Pliocene the genus seems to have reached a wonderful development and to have ranged over the greater part of the world; forms have been discovered in nearly every part of the world that man has visited. Near the close of the Pliocene it disappeared from Europe, but is found in the Pleistocene of America, sometimes associated with flint implements.

CARNIVORA.— The order *Carnivora* is one of the best known from the fossil forms. In the earliest Eocene they approach the *Condylarthra* to an extent that makes it difficult to tell the lines of the Ungulates and the Unguiculates (claw-bearing forms) apart. The earliest of the *Carnivora* are placed in a suborder, the *Creodonta* opposed to the suborder *Carnivora vera* which includes the recent Carnivores and their immediate ancestors.

Creodonta.— These animals show their approach to the carnivorous type by the development of specialized cutting teeth, the appearance of claws on the feet and the assumption of the general form of the modern carnivores. Recent investigations show that this suborder is perhaps the most primitive of the modern mammals and is to be considered the ancestor of the ungulate type. Osborn, in a discussion of the questions of paleontology, said: "The most primitive type of Condylarth (*Euprotogonia*) and of Amblypod (*Pantolambda*) as recently studied by Osborn and Matthew, strongly reinforces the hypothesis first enunciated by Cope, *that the source of the Ungulata is to be found in the Creodonta.* Upon the other side of the great Mammalian tree, the numerous branches of Unguiculates or primitive clawed types also have converged towards a Creodont ancestry, as seen especially in the characters of the Ganodonta, or ancestral Edentates, and of the Rodentia, if Matthew's supposition proves to be correct also of the Tillodontia. Thus all these groups should be added to the Carnivora as Creodont derivatives. The Carnivora extend back into Creodont prototypes; but, as in the case of the Artiodactyla and the Perissodactyla, the actual points of contact or links between the two divisions are yet to be discovered." He extends the discussion to the position of the Creodonta with relation to the primates. He says: "The point of contact of the primates with the Creodonta is still entirely wanting, but their relations appear to be here rather than with the Insectivora.

"In spite, therefore, of the many remaining deficiencies or absence of links in our paleontological evidence, it has none the less come about *that the Creodont type takes the central position which was assigned by Huxley in 1880 to the Insectivora*, for the known Creodonta are more generalized and more central than any other of the known Insectivora, fossil or living, the known Insectivora showing a very considerable specialization, especially in their dental succession, which places them apart as a distinct side phylum. This does not affect the derivation of the Creodonta themselves from stem forms of unspecialized Insectivora existing in the Jurassic period, the characters of which are seen in the *Insectivora Primitiva*, or placentals of the Stonesfield Slate and Purbeck periods."

The *Creodonta* are generally divided into eight families, which are here arranged as nearly as possible in the order of their evolution, which was directed toward the development of more perfect sectorial teeth and more and deeper convolutions on the surface of the brain.

Arctocyonidae: from the lowest Eocene of the United States, Puerco and Wasatch and the lowest Eocene of France.

Oxyclænidae: from the lowest Eocene of the United States.

Triisodontidae: from the lowest Eocene of the United States.

Mesonchyidae: from the Lower and Middle Eocene and possibly from the Miocene of the United States.

Proviverridae: from the Eocene of Europe and the United States.

Paleonictidae: from the Lower Eocene of the United States. This family is of some interest as containing the possible ancestor of the pinniped group of the true Carnivores.

Hyænodontidae: from the Eocene to the Miocene of Europe and America. This family has well-developed teeth of the sectorial type and approaches very close to the true carnivores.

Miacidae: from the Eocene of the United States. This family so closely approaches the modern carnivores that they have been placed among them by certain authors.

From the Lower Tertiary deposits of South America, Patagonia, come many forms that are undoubtedly Creodonts but of doubtful position in the suborder; by some authors they are placed among the *Hyænodontidae*, and by others they are placed in a separate group, the *Sparrassodonta*. The best known forms are *Prothylacinus* and *Borhyæna;* they are very similar in some respects to the carnivorous Marsupial, *Thylacinus*, of Tasmania.

The *Carnivora vera* are distinguished by the larger size of the brain with its deeper convolutions and the development of a single tooth in each jaw, the fourth premolar in the upper jaw and the opposing first molar in the lower jaw, as sectorial teeth. The suborder is generally divided into two groups : the *Fissipeda* or land living forms and the *Pinnipeda*, seals, walruses, etc.

Fissipeda. — Seven families are recognized, the *Canidae*, *Ursidae*, *Procyonidae*, *Mustelidae*, *Viverridae*, *Hyænidae* and *Felidae*.

Canidae.— The dogs appeared in the Upper Eocene of Europe and the Lower Miocene of the United States. They are descendants, probably, of the Proviverrine branch of the *Creodonta*. The development of the dogs has been toward the improvement of the feet as organs of locomotion ; the early forms had five toes on both the fore and the hind feet, but in the modern forms the first digit is wanting on the front foot and often on the hind foot as well. The teeth have developed from low crushing forms to the more typical carnivorous condition with the specialized carnassials. Typical forms are :

Cynodictis and *Cephalogale*, Upper Eocene, Europe.
Amphicynodon, Oligocene, Europe.
Amphicyon and *Galecynus*, Miocene, Europe.
Daphænos and *Oligobunis*, North American Miocene.

The recent forms appeared in the Pliocene of Europe, Asia and North America, and in the Pleistocene of Africa and South America.

Ursidae.— The bears are distinguished by the plantigrade feet and the low multitubercular teeth without the specialized carnassials. They appeared in the Middle Miocene of Europe in the genus *Hyænarctos* and not before the Pleistocene in the other countries when the existing genera were developed.

Procyonidae.— The coons occupy a small place somewhere between the dogs and the bears. They were developed some time in the Pliocene and are today confined to the American and the South Asian regions. They are known from the Loup Fork beds of the United States.

Mustelidae.— The weasels and otters are among the most specialized of the *Carnivora.* The first live almost entirely upon blood drawn from the veins of their victims and the second are aquatic in habit and great eaters of fish. They began their development in the upper Eocene and in that time and the Miocene a large number of forms were developed in Europe. After the Miocene they spread out and the deposits of all parts of the world, with the exception of Australia, are rich in their remains.

Viverridae.—A small group of cat-like animals confined to Africa, Asia and Southern Europe. They originated in the Eocene of Europe and only as late as the Pliocene appeared in others countries.

Hyænidae.—The hyænas are somewhere between the cats and the bears, the teeth are partly sectorial and partly crushing in form. They appeared in the Upper Eocene of Europe and Asia and are now known from those deposits with the addition of North Africa. *Hyænictis* is one of the first forms. It is from the Miocene of Europe and Asia.

Felidae.—The cats reach, perhaps, the highest point of the development of the *Carnivora.* The teeth are highly specialized; the molars seem to show a tendency to grow less in number and to assume more and more the form of the feline carnassials which are the highest type of that tooth form developed. The fore feet are modified to serve as organs of prehension as well as locomotion. The canine tooth reaches enormous proportions in some forms, and there is a process on the lower jaw to protect them as in the *Dinocerata.* They originated in the Upper Eocene and rapidly spread all over the world. The Oligocene, White River, of the United States is especially rich in the remains of these forms.

Eusmilus.—Upper Eocene of Europe.

Hoplophoneus, *Dinictis*, *Nimravus* and *Pogonodon.*—White River, United States.

Machairodus.—Pliocene, Europe, Asia, and the Americas. This form is remarkable for the great length of the upper canine. It was so long that it is possible that the animal could not open its mouth wide enough to bring the teeth into play. It has been suggested that the teeth were used to aid it in climbing trees.

The existing genera of the cats were developed in the Pliocene and Pleistocene.

Pinnipeda.—The water living carnivores seem to have sprung, as has been suggested, from the Creodont *Patriofelis.* The existing families can be traced back as far as the Pliocene but beyond that there is nothing to connect them with the early forms. Fragmentary skeletons of seals and walruses have been found in the Pliocene of Europe and America.

INSECTIVORA.—The Insectivores are among the least changed of all the Mammals from their prototypes of the earliest Tertiary. The brain, carpus and dentition all present characters that are found in the Creodonts. Many of the existing families are found in the Eocene.

CHIROPTERA.—The bats are known from deposits as early as the Eocene in Europe and America, but nothing is known of their ancestry; the fossil genera, including those extinct, are very similar to the living forms.

RODENTIA.—The order is characterized by the absence of the canine teeth, the development of two incisors in the upper and the lower jaws as gnawing teeth which grow from persistent pulps and the arrangement of the articular condyle so that the lower jaw can slide backward and forward in the act of grinding up the food. There are many primitive characters in the group which is a remarkably persistent one, well-defined rodents being known from the early Eocene. Three suborders are known: the *Tillodontia*, *Duplicidentata* and the *Simplicidentata.*

Tillodontia.—These are forms that are known from the Eocene deposits of Europe and America. In these the canines are still preserved as rudiments, and there are sometimes more than the single pair of incisors in the lower jaw.

Esthyonx from the Wasatch and Bridger series of the United States is the earliest form known. A fragmentary skull from the London Clay seems to indicate the presence of a related form in Europe.

Tillotherium from the Bridger of the United States is the largest form known; the skull measured about a foot in length. The developed incisor teeth are of large size, and the second pairs of incisors and the canines are even smaller than in the preceding genus.

Duplicidentata.—This group contains the hares and rabbits. They seem to have been developed about the Middle Miocene, *Paleolagus*, White River. During the Pliocene they spread over all of Europe and North and South America.

Simplicidentata.—This group is far larger than the preceding; it contains the rats, mice, squirrels, and all the remaining forms of the rodents. None of the forms appear before the Miocene, and during that time and the Pliocene differentiated and spread all over the world.

PRIMATES.—The order is divided into two suborders, the *Lemuroidea*, containing the lemurs, and the *Anthropoidea*, containing the apes and man.

Among the primitive lemurs are many forms which are so clearly intermediate between the two suborders that they must be regarded as the direct ancestors of the *Anthropoidea.* The living lemurs are confined to the island of Madagascar and to parts of Africa and southern Asia. In the Miocene and Eocene times they seem to have spread over the greater part of Europe and North America; they became extinct in the latter countries about the end of the Miocene time. Among the most important forms of the lemurs are *Anaptomorphus*, *Adapis* and *Megaladapis.*

Anaptomorphus is from the Wasatch Eocene of Wyoming; related forms are known from the lower Eocene of France and England. The animal exhibits the very large cerebral hemispheres that are characteristic of all the Primates and thus indicates the starting point of the specialization in the nervous system that has culminated in man.

Adapis is from the Lower Eocene of Europe; a closely related form is *Tomitherium* from the Eocene of New Mexico.

Megaladapis is a very large form from the post-Pleistocene of Madagascar. The skull was about two feet long. The animal seems to have lived in the island as late as the seventeenth century.

Anthropoidea.—The true apes do not appear until the middle of the Miocene; in Europe they seem to have extended over a large part of the continent as late as the Pliocene time, and one genus still exists upon the rock of Gibraltar. The genera of the apes multiply so rapidly that it is not possible to trace the development of the forms in any limited paper. It will perhaps suffice to note their occurrence in the Middle Miocene of France, the Pliocene of Germany, the Pliocene and Pleistocene of India and the early Tertiary of Patagonia.

In regard to the derivation of the human family, *Hominidae*, from the Primates Cope says (*Primary Factors of Organic Evolution*, chap. 11, p. 157. The phylogeny of man): "To return to the more immediate ancestry of man I have expressed and now maintain as a working hypothesis that all the Anthropomorpha were descended from the Eocene lemuroids. In my system the Anthropomorpha includes the two families Hominidæ and Simiidæ. The sole difference between these families is seen in the structure of the posterior foot, the Simiidæ having the hallux (great toe) opposable, while in the Hominidæ the hallux is not opposable. . . . . " "It is then highly probable that Homo is descended from some form of the Anthropomorpha now extinct, and probably unknown at present, although we do not yet know all the characters of some extinct supposed Simiidæ, of which fragments only remain to us."

Smith Woodward says of the earliest men: "Most of the evidence for the existence of the human race in the pre-historic past consists in traces of intelligent handiwork revealed by stone and other implements. A few discoveries in the old world, however, are worthy of consideration.

"The oldest known traces of a man-like skeleton seem to be an imperfect roof of a skull, two molar teeth, and a diseased femur, from a bed of volcanic ash containing the remains of

Pliocene mammals, near Trinil, in central Java. These are believed to belong to one animal which has received the name of *Pithecanthropus erectus.* The capacity of the brain-case is estimated to have been about two-thirds the average of that of man: the forehead is very low; and the supraorbital ridges are prominent. The inclination of the nuchal surface of the occiput is considerably greater than in the Simiidæ. The femur measures 0.455 m in length, and denotes an upright gait.

"The oldest human skeletons of which the geological age is determined with certainty, are two from the cavern of Spy, near Namur, in Belgium. These were found in association with remains of the mammoth and other Pleistocene mammals beneath a layer of stalagmite, which had never been disturbed, and which was also covered with earth containing bones of the same extinct quadrupeds. The skeletons, therefore, could not be the result of a comparatively recent burial, but were proved to have been contemporaneous with the associated animals and Palæolithic flint implements. They are essentially human in every respect, but seem to represent a race inferior in skeletal characters to any now existing. They are small, but powerfully built. The forehead is low; the supraorbital ridges are very prominent; and the chin is remarkably retreating. The radius and ulna are unusually divergent in the middle. The femur is somewhat bent, and the tibia is comparatively short, so that the leg cannot have been quite upright in walking. This type is now generally known as the *Neanderthal race*, the roof of a similar skull having been found associated with other fragmentary remains so long ago as 1857 in a cavern in the Neanderthal between Düsseldorf and Elberfeld, Germany."

In closing the discussion of the mammals, it is well to draw attention to the idea so forcibly set forth in Lydekker's book, *Geographical History of the Mammalia*, that all the mammals had a northern origin, and have attained their present position by gradual migration toward the south. Though the theory is still far from being proven, it should be of great interest to the student of geology because of the possibilities it presents for an interpretation of climatic and land-mass conditions in the Tertiary time. Throughout the book evidence is constantly adduced to show the strength of the author's position. I shall quote merely enough of the introduction to give an idea of the theory.

Upon page 7 the author says: "There is a considerable probability that at least a very large proportion of the animals that have populated the globe in the later geological epochs originated high up in the northern hemisphere, if not, indeed, in the neighborhood of the pole itself (which is known to have enjoyed a genial climate during the Tertiary period), and that they gradually migrated southwards in a series of waves, probably under pressure of the development of new and higher types in high latitudes; and it is to such southerly migrations that the present marked differentiation of the fauna of different parts of the earth's surface is chiefly due. Whether such a northerly origin held good for the terrestrial life of the Secondary epoch, there are no means of determining; but it would appear that the higher animals (which were chiefly reptiles) of that epoch were very similar throughout the world, and that the differentiation of faunas had scarcely, if at all, commenced." . . . . "With mammals the case is very different. The earliest known forms, which date from the Triassic and Jurassic rocks, are chiefly marsupials and forms apparently allied to the monotremes, and it is probable that most of the descendants of these, as is more fully indicated in the sequel, migrated southwards during the early part of the Tertiary epoch, to find in Australasia a refuge from the competition of higher forms. Of the higher placental mammals, none of the modern types make their appearance before the Oligocene and Miocene periods, while many do not antedate the Pliocene. Their southern migrations accordingly took place later on in the Tertiary period, one of the earliest movements being the wandering of lemuroids, insectivores, and civet-like carnivores into South Africa and Madagascar. On the other hand, many other higher types, such as the hippopotami, giraffes, and antelopes, which were abundant in Europe and southern

Asia during the Pliocene, only left their more northern homes to find a permanent abiding place in Africa at a very late epoch in the earth's history."

E. C. CASE.

References.—Other than the books already referred to, the student will find the most helpful literature in the files and current numbers of *The American Journal of Science, The American Naturalist,* which contains a number of separate articles upon the different groups, by the late Professor Cope, the *Proceedings of the Philadelphia Academy of Science,* the *Proceedings of the American Philosophical Society, The American Geologist,* and *The Kansas University Quarterly.*